Influence of India's transformation on residential energy demand

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Abstract

India's recent macro-economic and structural changes are transforming the economy and bringing significant changes to energy demand behaviour. Life-style and consumption behaviour are evolving rapidly due to accelerated economic growth in recent times. The population structure is changing, thereby offering the country with the potential to reap the population dividend. The country is also urbanising rapidly, and the fast-growing middle class segment of the population is fuelling consumerism by mimicking international life-styles. These changes are likely to have significant implications for energy demand in the future, particularly in the residential sector. Using the end-use approach of demand analysis, this paper analyses how residential energy demand is likely to evolve as a consequence of India's transformation and finds that by 2030, India's commercial energy demand in the residential sector can quadruple in the high scenario compared to the demand in 2010. Demand for modern fuels like electricity and liquefied petroleum gas is likely to grow at a faster rate. However, there is a window of opportunity to better manage the evolution of residential demand in India through energy efficiency improvement.

Keywords: life-style changes, energy demand, India.

[This is the unedited, pre-publication version of the paper accepted for publication in Applied Energy. The published version will be available in the journal site in due course.]

Contents

1.0 Introduction

Rapidly changing India is at a crossroads. With more than 1.2 billion people, currently it is the second most populous country in the world and based on the current population growth trend, the UN population projections suggest that India will surpass China to become the most populous country in the world within a decade, by 2021 [1]. It was the tenth largest economy in 2011 (with GDP measured in exchange rate terms), but a faster economic growth in the recent past and the prospect of maintaining a reasonably high economic growth in the coming years has brought the prospect of becoming the third largest economy in the world, only after China and the US, by 2030 [2]. Simultaneously, the size of the Indian middle income class has doubled between 2002 and 2010 (from 50 million to 100 million)[3], and has helped in pulling 137 million out of poverty between 2005 and 2012 [4]. Moreover, the country is urbanising rapidly and the share of its urban population is expected to reach 40% by 2030 from its present 30% share [5]. Furthermore, western consumerism is on the rise since the opening up of the economy in the 1990s when Indian economy started to integrate with the world economy. The rise of information technology as an important service sector activity in the country and greater international mobility of Indian workforce since late 1990s has influenced a catch-up with western consumerism. All these changes are taking place when the country is undergoing a demographic transition, which can play an influential role in the country's future, particularly on energy demand.

The purpose of this paper is to provide estimations on the future energy demand (until 2030) in the residential sector in India, thereby specifying the consumption of wood, kerosene, liquefied petroleum gas (LPG), coal and electricity. The methodology takes into account the demographic evolution of India. For an accurate estimation, the consumers have been divided in rich, poor and middleclass categories, and in urban and rural consumers. For the demand growth different assumption are taken and these are represented into three scenarios. Based on this grouping, the number of inhabitants in each group and the specific consumption, the energy demand for each fuel has been calculated until 2030.

A brief review of relevant literature on the subject, presented below, establishes the knowledge gap and justifies the need for this research. A number of studies have looked at the influence of changing life-style on energy demand in India.

Using 1993-94 household expenditure survey data, Ref. [6] has analysed the household energy demand in India using the econometric method and aimed at identifying the relevant drivers of household energy demand. Ref. [6] found that household energy expenditure per person has the most significant influence on residential energy demand but other attributes such as dwelling types, family characteristics, and demographics also influence energy demand.

Reference [7] has estimated the elasticities of electricity demand in urban households considering the differences in electricity elasticity in three seasons of the year (winter, summer and monsoon). It has found that urban electricity demand is highly income elastic but the own price elasticities of residential electricity demand are lower than other studies while the income elasticities were similar to other studies. However, these studies used an older data set and the purpose was not to

understand the future energy demand in the residential sector taking India's transformation into consideration.

In contrast to econometric studies mentioned above, ref. [8 and 9] relied on the end-use approach to understand the future energy demand in the residential sector in India. Ref. [8] is concerned with residential electricity demand for India in 2031-32 and used the household expenditure survey of 2004-05. It projected urban and rural household distribution and their expenditure on an annual basis and forecast appliance ownership to estimate future electricity demand. The analysis considers a reference case and an alternative case where the penetration of more efficient technologies is considered. The study estimates an annual average demand growth of 5.8% in the reference case and a significant potential for demand reduction in the alternative case.

Ref. [9] focused on both residential and transport energy demand in 2020 but used 1999-2000 sample survey data. It found that electricity consumption per household will quadruple between 2000 and 2020 and energy used by cars is likely to grow at an annual rate of 11% during this period. Despite their importance, these studies relied on older data sets and did not consider the possibility of an accelerated economic growth in India.

Ref. [21] uses a disaggregated end-use model wherein five end-use categories (namely cooking, water heating, space heating, lighting and appliances) are considered for five different income quantiles in rural and urban areas. The demand is analysed considering economic growth, population change and income distribution changes. The study reports that the residential energy demand is expected to increase by 65-75% in 2050 compared to 2005 base line.

Using an input-output based approach Ref. [18] analysed and compared the direct and indirect energy demand in Indian households over a ten year period (1983/84-1993/94). Combining the data from household expenditure survey with energy intensity information, the study attempted to capture the implications of household energy demand on India's overall primary energy demand. It reveals that 75% of the total primary energy use in India originates directly and indirectly from the household energy demand. The study relied on an older set of data and used a representative consumer. It also did not capture the urban-rural differences in energy use in India.

Ref. [19] has compared the changes in residential energy demand in India between 1993-94 and 2006-07 using input-output approach. Using a detailed inter-industry transaction matrix, the study captured the direct and indirect residential demands and found that house building and recreation have recorded maximum changes in demand during the study period. However, the work did not consider future demand and the effects of structural transformation in India on residential demand.

Ref. [20] presents a comparative descriptive analysis of household energy transition in China and India using household surveys in both countries. The analysis considered three indicators, namely changes in the quantities of energy used, changes in the percentage of persons using different types of energy and the shifting pattern and structure of household energy consumption. It found that the urban households consume more commercial energies than their rural counterparts in both the countries but more total household energy is used in the rural areas due to high reliance on inefficient fuels. While this study touches on household energy transition, it does not focus on future implications of structural and behavioural changes and relies on an older data set for India.

Ref. [22] presents a long-term energy demand assessment of the building sector considering increasing population, income and urbanisation. It uses a technologically-detailed, service-based model and finds that as India's per capita income increases to the developed country levels, the building energy demand will increase following the footprints of the developed countries. However, the study focuses on the building sector – not the residential sector.

Ref. [23] uses the Regional Energy Model to investigate rural electrification options in India between 2005 and 2030. However, this is about rural electrification and not about residential energy demand. There are many other studies on residential energy demand in other countries – see Refs. [24-27], but their focus tend to be different compared to the issues considered here. For example, Ref. [24] presents a model of US residential energy demand by combining regression and artificial neural network approaches. Ref. [25] analysed the case of UK using the MARKAL model. Refs. [26 and 27] used index decomposition technique to analyse residential energy demand. However, there is a dearth of studies focusing on the pressing issues facing the Indian residential energy sector.

The above review shows that while residential energy demand in the Indian context has been analysed, there exist two main issues with the previous studies: a) first, most of them have relied on older data based on earlier sample surveys of 2001 and 2004-05 whereas more recent data is now available that can provide new insights into the issue; b) second, none of the previous studies has captured the multi-dimensional transformation taking place in India and the effects of demographic transition, urbanisation and changes in consumption pattern due to income effect have not been adequately analysed. An accurate estimation of the effect of ongoing transformation on residential energy demand needs to consider the changes in the population mix, income distribution, urbanisation and economic development in the future. This paper aims to bridge this knowledge gap by analysing the influence of macro-economic and demographic changes on energy demand with a particular emphasis on household demand using a more recent data at a disaggregated level considering urban and rural consumption patterns separately.

The paper is organised as follows: following introduction, a review of transition dimensions is presented. This is followed by a review of changing consumption pattern, with special reference to energy use in urban and rural areas. The analysis of residential electricity demand in the 2030 horizon is then presented. Finally, the concluding remarks are presented wherein suggestions for residential energy demand management are also indicated.

2.0 STRUCTURAL AND MACRO-ECONOMIC CHANGES IN INDIA

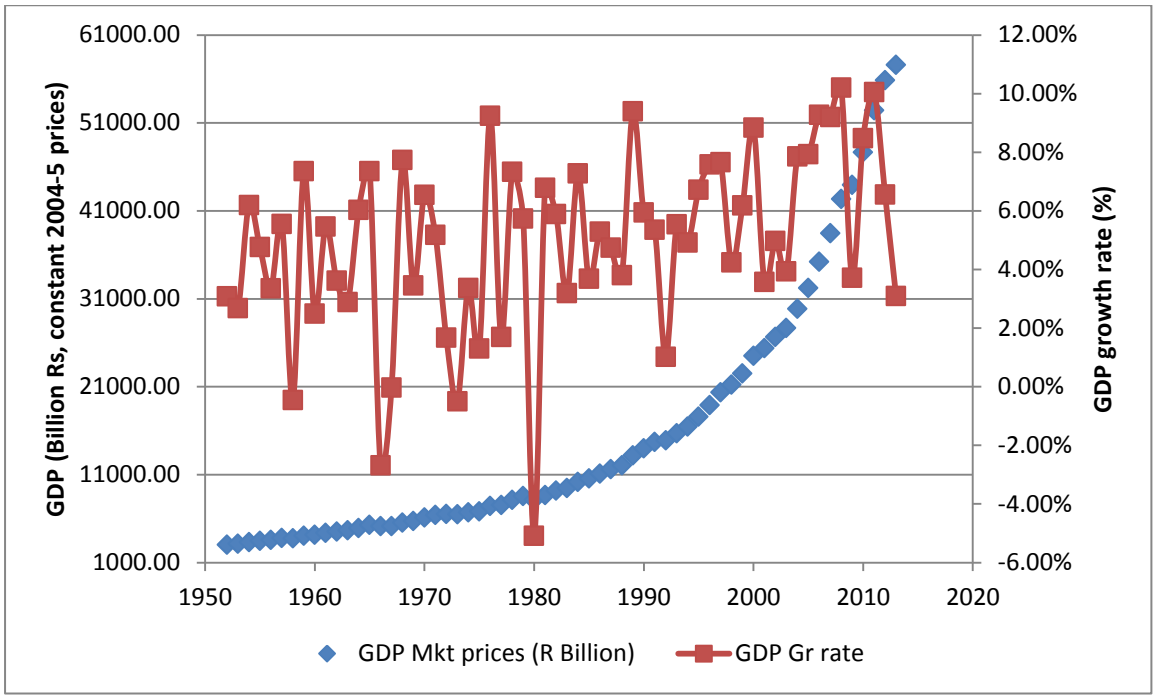
India has experienced two major developments in recent times: the economic outlook has improved and her demography is undergoing a structural change. This section provides an overview of these changes to set the scene for the analysis.

2.1 Economic outlook

Figure 1 clearly reveals that India's GDP has grown exponentially over the past six decades but the hill and trough pattern of the growth since 1950s can be easily verified. The average growth rate has

gradually progressed over time to a higher growth path in recent times, with an average growth rate of 4% per year prior to 1970s to about 7% growth rate per year in the last decade. This becomes even more impressive when the global economic recession is taken into consideration. However, in contrast to China which has managed to sustain high rates of economic growth over three decades, India failed to sustain regular spells of growth take-offs. Each spell of growth was quickly followed by economic downturns but the average period of such spells has increased in recent times. Analysts believe that despite some signs of temporary slow-down in recent times, the overall growth prospect remains good [4] and the country is likely to become the third largest economy in the world by 2030 [3, 4].

Fig. 1: Trend of Indian economic growth



Data Source: [9] RBI Handbook of Statistics, 2013

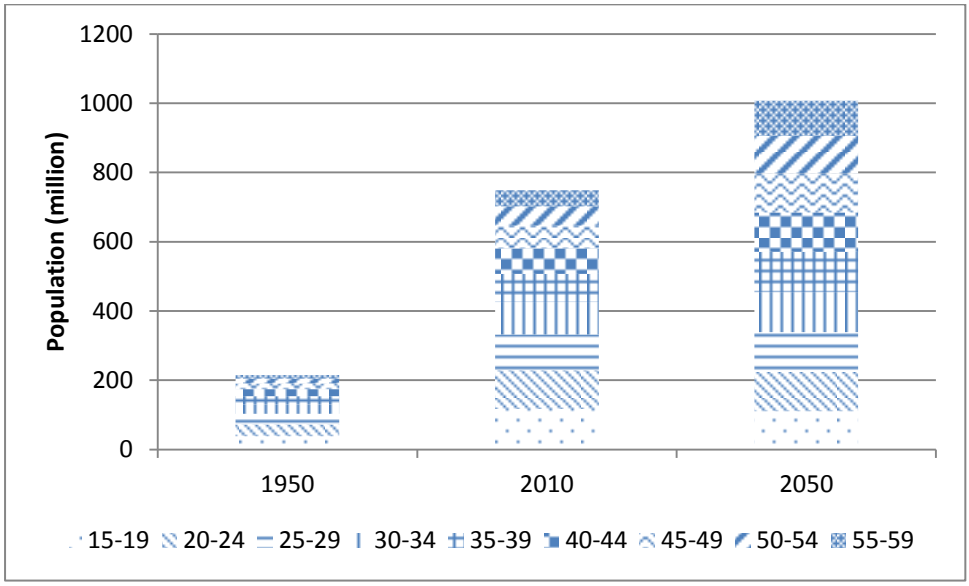
Ref. [12] provides a number of reasons for the optimistic outlook. The economic climate has improved due to liberalisation of the economy in the 1990s and 2000s, and consequently the economy has seen a growth in investment. The fixed investment has gradually increased to 35% of gross domestic product (GDP) in recent years compared to about 20% in the 1980s. The performance of the manufacturing sector is improving and the service sector has emerged as a major player. Both the sectors are driving growth and job creation. The interest burden arising from public sector borrowing is falling with respect to GDP. India is also likely to benefit from the neighborhood effect due to proximity to other faster growing countries in the region. The domestic market is also increasing due to the growing size of the middle income class. While governance and political decision-making issues have affected economic growth, a recent change in the government in India in 2014 has once again brought new hopes for faster economic development in the country.

2.2 Demographic transition

India's population has grown four-fold between 1901 and 2011, from 238.4 million in 1901 to 1021 million by March 2011 [13]. The average growth rate is showing a declining trend now but because of the size of the young population, the country will take a considerable amount of time before her population stabilises. According to the UN population forecasts, India's population will grow to 1.46 billion by 2025, and to 1.69 billion by 2050, thereby increasing her share to more than 18% of the global population [1]. India is projected to overtake China in population count by 2021 and become the most populous country in the world. This assumes importance as India occupies only 2.4% of the global surface area but is likely to support more than 18% of the global population [13].

Simultaneously, the structure of India's demography is also changing (see Fig. 2). In 1950, India had 215 million people in the working age (aged between 15 and 60) whereas in 2010, this has more than trebled to 748 million. The same trend is projected to continue over the coming decades and the size of the working age population will increase to 944 million [14]. This indicates that the ratio of working-age population to that of non-working age population will improve and peak around 2040 [14]. This demographic change places India in a "sweet spot" [3] as the country will have less dependents to take care of and the population will have higher disposable income. Out of 300 million new labour force forecasted globally by 2030, India is likely to provide 200 million [3].

Fig. 2: Evolution of working age population in India



Legend: age distribution

Data source: [13]

2.3 TRANSFORMATION OF THE COUNTRY

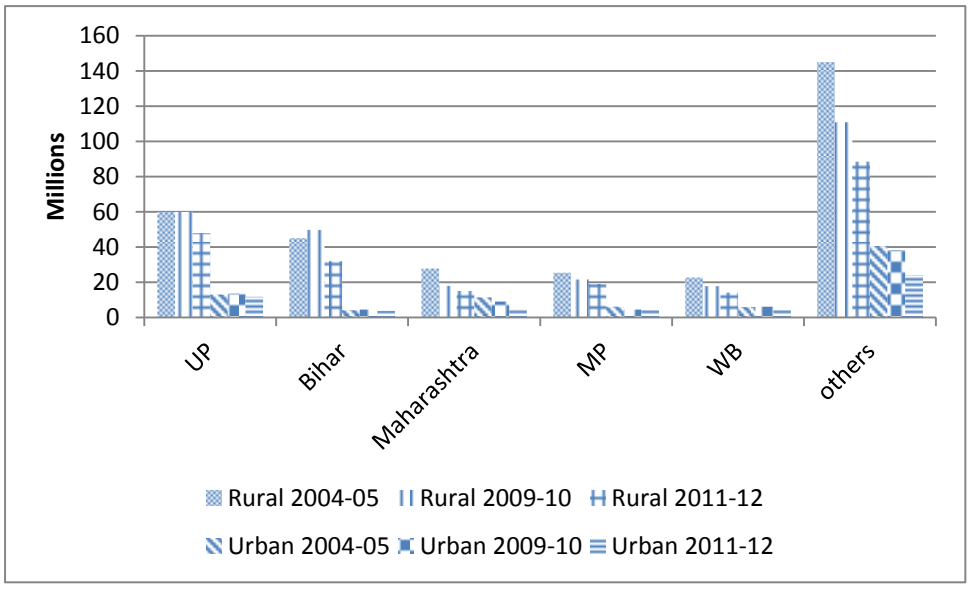
As a consequence of economic growth and demographic transition, the level of poverty has fallen sharply, the middle income class is growing and the country is facing rapid urbanisation. These developments are briefly reviewed below.

2.3.1 Economic growth reducing poverty

Better economic performance in recent times has helped the country in its fight against poverty. According to [11], about 22% of the population were below the national poverty line in 2011-12 financial year, which represents about 270 million people. Poverty is more pronounced in rural areas (25.7%) compared to urban areas (13.7%). While Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh and Uttar Pradesh have high rates of poverty in terms of percentage of population, in absolute numbers Uttar Pradesh, Bihar, Maharashtra, Madhya Pradesh, and West Bengal account for almost 58% of the poor in the country.

However, Ref. [16] indicates that the economic reforms have helped 103 millions to come out of poverty since 1985 while Ref. [3] suggested that 137 million have been lifted out of poverty between 2005 and 2012, which is confirmed by Ref. [11] – indicating that the size of the poor has reduced from 407 million in 2004-05 to 270 million in 2011-12. Major gains in poverty reduction can be noticed in states with major concentrations of poor people as well as in the rest of the country (see Fig. 3). Clearly, the trend is downwards and Ref [15] indicates that if the economy continues to grow at a reasonably high rate, another 291 million will be out of poverty over the next two decades.

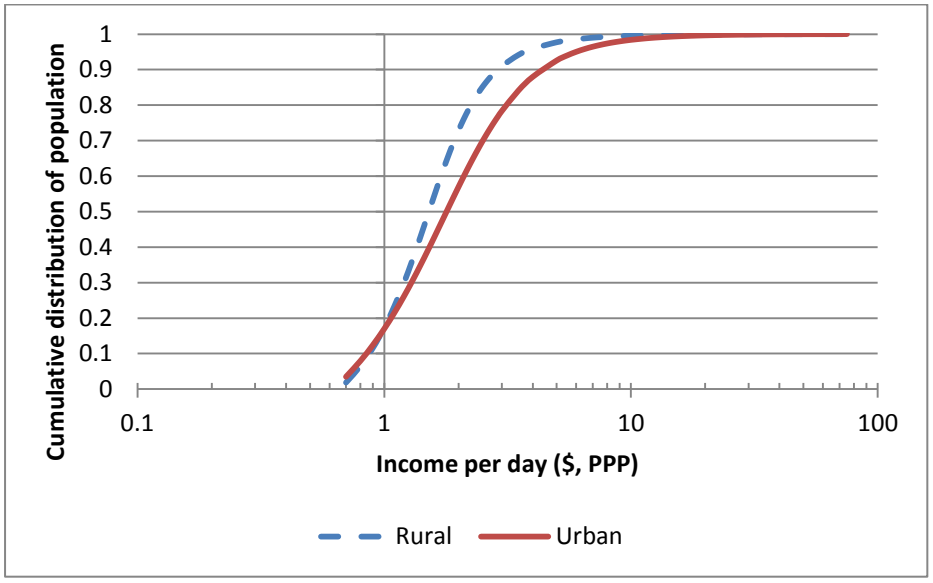
Fig. 3: India's fight against poverty



Data source: [11]

Despite this reduction in poverty incidence, poor income distribution remains an issue (see Fig. 4). Yet, it is clear is that the urban population is slightly better off compared to their rural counterpart, and a shift towards the right as a result of higher economic growth will bring poverty down in the future. This has the prospects of significantly increasing the middle income class in the future, which is discussed below.

Fig. 4: Income distribution in India in 2010



2.3.2 Growing middle income class

As a consequence of faster economic growth and the demographic transition, the size of the middle income class is growing fast in India. A recent report [3] indicates that there is a visibly growing middle class in India. Ref. [12] suggests that India could see her middle income class swell from 5-10% of its population today to 90% in three decades. He suggests that between 2015 and 2025, half of India's population will have income above $10 per capita per day. Using a slightly restricted definition of middle class Ref. [16] finds that by 2025, India will have 583 million people (or 41% of the population) in the middle income bracket. They will account for 58% of the total Indian income and will constitute the next generation of big spenders.

In this study, the following approach is used to obtain the distribution of population by income class for the future: the distribution is obtained using the Lorenz Curve, for which parametric estimation was done using PovCal software of the World Bank and the NSSO 2010 survey data was used to estimate the parameters. Assuming that the future distribution of urban and rural population by income class follows the same distribution as in 2010, and that the economy grows at an average rate of 7% per year for the entire period of study (2010-2030), the urban –rural distribution of population by class is arrived at. Following Ref. [12] three income groups – poor, medium income

and rich – are used separately for urban and rural population. Like Ref. [12] it is assumed that a household of 4 members with a daily income below $10 (in PPP terms) is poor, while those falling within $10 and $100 are middle income households. Any household with an income beyond $100 per day income is considered as rich.

The expected distribution of population by income decile is presented in Fig. 5 and Fig. 6. As indicated above, the distribution does not change as such but shifts rightwards as income improves as a result of economic growth. As a consequence, the size of Indian poor dramatically reduces and the middle income group swells exponentially. By 2030, 95% of the urban population and 93% of the rural population is likely to enter the middle income category. The size of the rich is likely to reach 4% of the urban population (or about 23 million) by 2030. These demographic changes along with growing income will dramatically change the consumption characteristics in India in the future.

Fig. 5: Income distribution of rural Indian population up to 2030

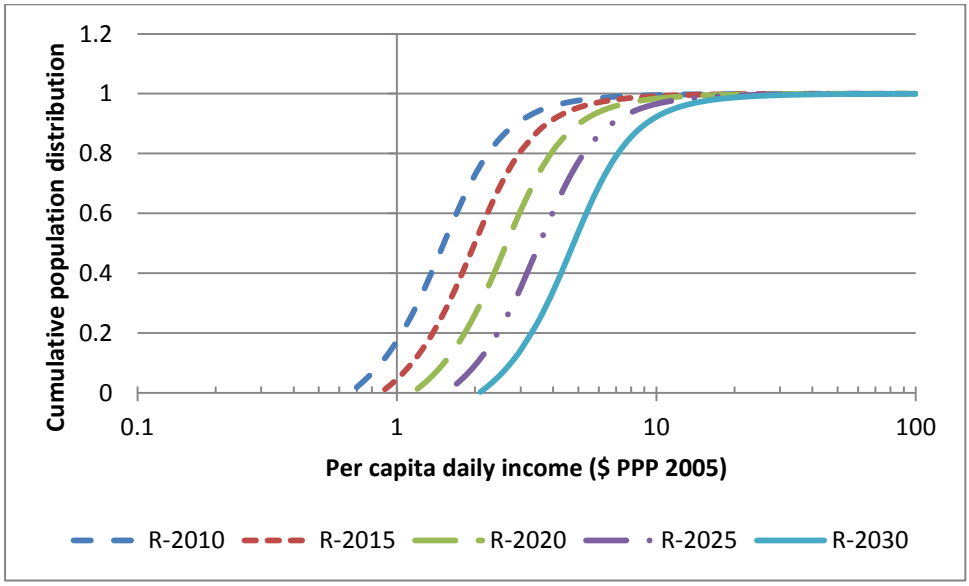
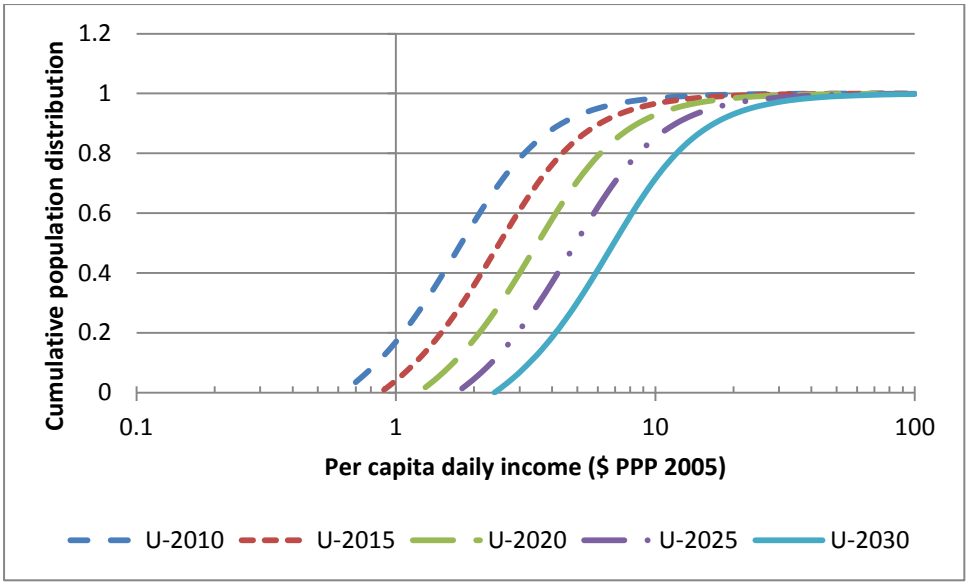


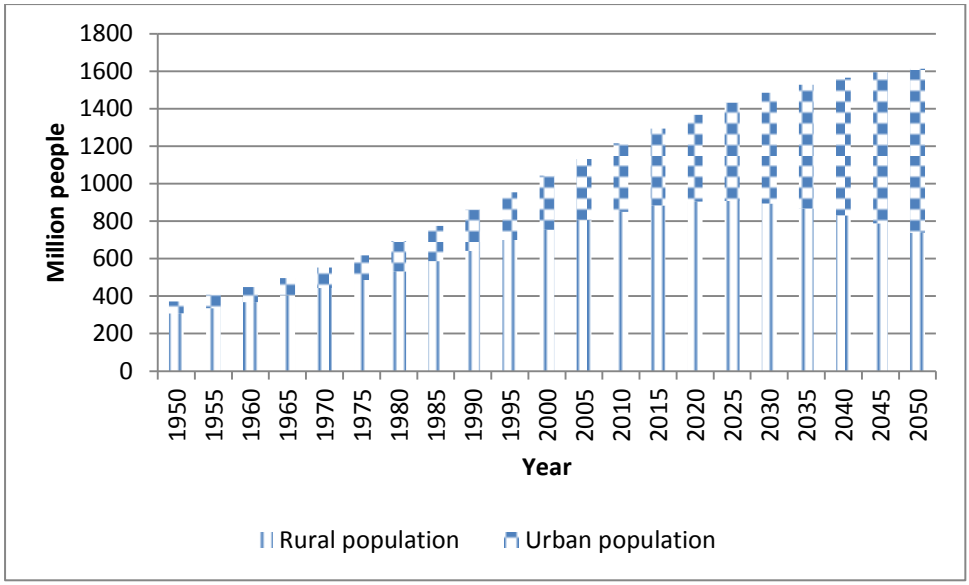
Fig. 6: Income distribution of urban Indian population up to 2030



2.3.3 Rapid urbanisation

According to Ref. [14], about 30% of the Indian population lived in urban areas in 2010 and the size of Indian urban population has grown to 364 million in 2010 from 63 million in 1950. Since 1990, India has added 144 million urban dwellers, and the UN estimates that the share of urban population will reach 40% by 2030 and 54% by 2050 [14] (see Fig. 7). This implies that another 226 million people will be added to the country's cities within the next two decades, and more than 510 million by 2050 [14]. According to Ref. [10], the size of India's urban population in 2030 will be twice the US population today. This rate of urbanisation is unprecedented in the world, except, of course for China, and will have serious implications for the country and the world. Ref. [8] indicates that 70% of India's GDP in 2030 is likely to come from its urban areas and has the potential of driving a four-fold increase in the per capita income by 2030. Simultaneously, the size of the middle class population will grow four-fold to 147 million from the present level of 32 million.

Fig. 7: Urban-rural transition in India



Data source: [14]

A consequence of rapid urbanisation is that the urban population is contributing to an ever-increasing share of the economic growth of the country. Reference [10] indicates that in 1995, the urban- rural share in the GDP was almost equal; by 2008, the urban share had increased to 58% of India's GDP and 70% of India's GDP in 2030 is likely to come from its urban areas. This also has the potential of driving a four-fold increase in the per capita income by 2030.

The reduction in poverty, rise of the middle-income class and rapid urbanisation are likely to influence future energy demand, particularly in the residential sector. Already, the consumption pattern of energy and non-energy goods has started to evolve. This is discussed below.

3.0 Evolving consumption pattern in India

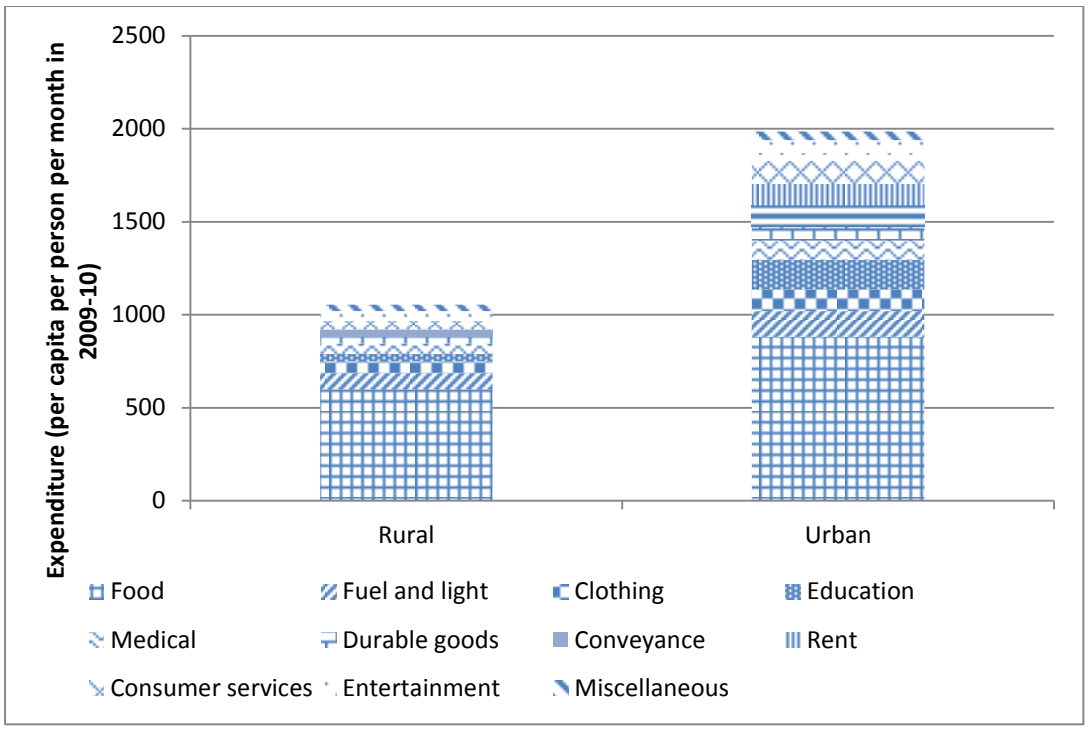
Information on the changing consumption and spending behaviour is available from a recent national survey, which is presented below.

3.1 Urban-rural consumption differences

According to Ref. [17], which reported the 66th round of National Sample Survey on household consumption, an urban consumer has spent almost twice that of his rural counterpart in 2009-10 and the spending pattern is significantly different between the urban and rural areas (see Fig. 8). In monetary terms (Rupees per capita per month), an urban consumer spends 95% more on average compared to his rural counterpart. While for food items, an urban consumer spends about 46% more than his rural colleague, the spending disparity in non-food items is even more pronounced

(more than 260% higher). This is due to a high level of spending on rent (for accommodation) and education, for transport and on durable goods.

Fig. 8: Differences in expenditure pattern in rural and urban India



Data source: [17]

The difference in the spending pattern reveals the following:

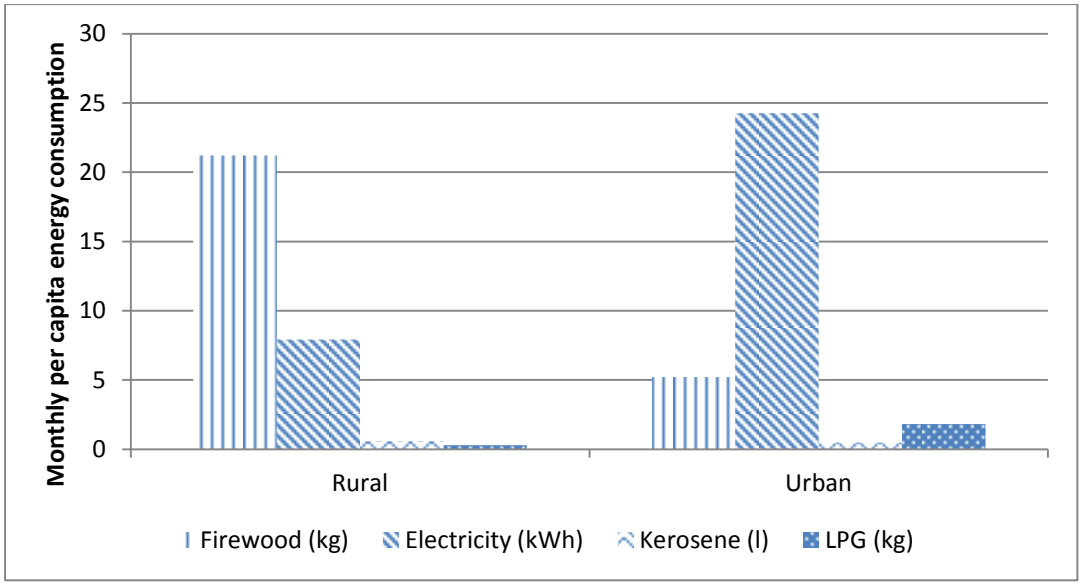
- A rural consumer spends a larger share of his income on food (57% accounts for this whereas his urban counterpart spends about 44% of his budget). On average, food remains a major expenditure item in both urban and rural areas.
- Urban dwellers spend 8% on education, 7% on energy related costs, and 6% on clothing. Rent, transport, other consumer services, entertainment and medical expenses get very similar priorities in the consumption spending decision. Durable goods come at the end of the spending list – with a 4% expenditure share.
- An average rural consumer on the other hand, spends 8% on energy, 6% on clothing and 5% on medical expenses. Education, consumer services and durable goods receive lesser priority in terms of spending.
- Clearly, the higher priority to education for the urban dwellers is also a distinctive feature. The recognition of better education for a better future, and higher peer pressure and competition in education can explain the high level of expenditure in this regard.

The spending pattern reflects the differences in the income level in rural and urban areas and the sample data points to significant rural-urban disparity existing in the country.

3.2 Energy consumption pattern in rural and urban households

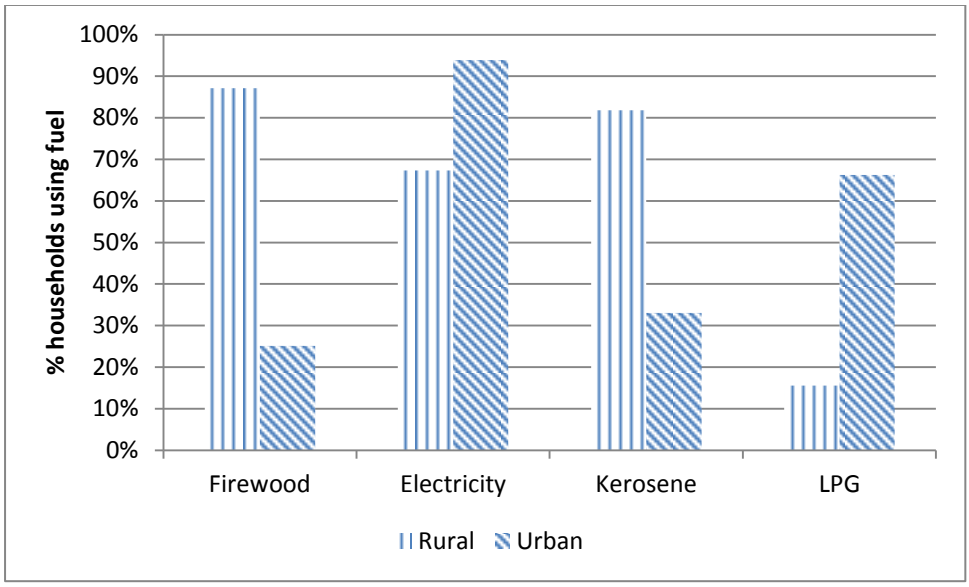
Ref. [17] provides detailed information about various spending categories. A closer look at some of the specific items such as expenditure on energy and durable goods reveals interesting features. The difference between the consumption pattern and the fuel mix of energy use by rural and urban consumers is presented in Fig. 9 and 10. It becomes evident that both rural and urban households rely on a mixture of modern and traditional forms of energy. For example, 87% of rural households use firewood, 82% still use some amount of kerosene, 67% use electricity and 15% use LPG. On the other hand, 94% of urban households use electricity, 66% use LPG, 33% use kerosene while 25% still use some firewood. The fuel choice reflects the level of access to modern energies as well as consumers' ability to pay for a fuel and related government interventions. In terms of per capita consumption rural households use 21 kg of firewood per month while the urban households are using about 5kg of firewood and 1.8 kg of LPG per person per month. While an urban consumer used about 24 kWh per month, a rural consumer consumed only about 8 kWh per month. Limited affordability of rural consumers and limited ownership of electric appliances as well as supply constraints explain the difference in rural-urban electricity consumption behaviour.

Fig. 9: Urban-rural energy use difference in India



Data source: [17]

Fig. 10: Share of households using different energies



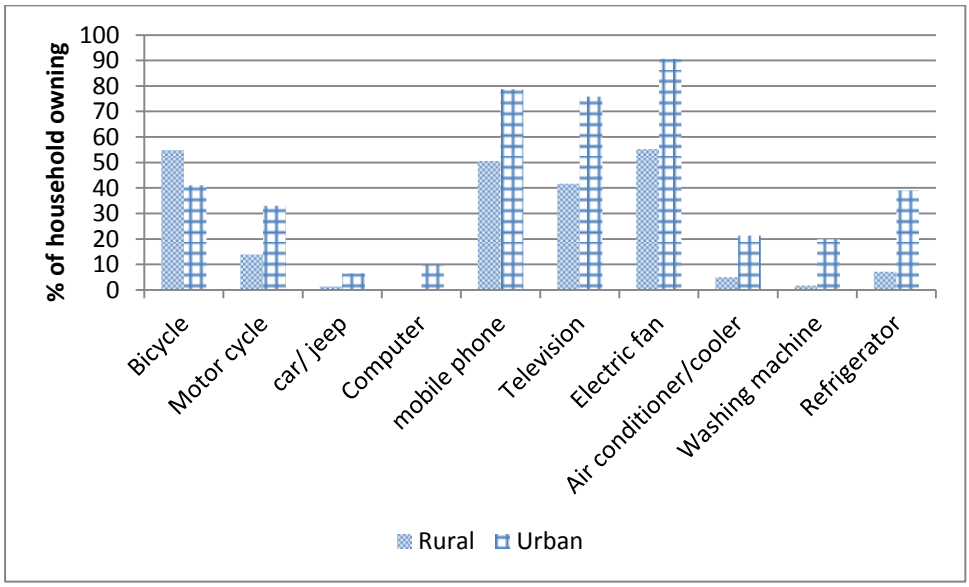
Data source: [17]

3.3 Ownership of durable goods

The ownership pattern of durable goods in urban and rural areas of India reveals interesting insights (see Fig. 11). More than 50% of rural households possess bicycles, electric fans and mobile phones. The proliferation of mobile phones even in rural India is particularly noticeable. However, the ownership of white goods or motor vehicles in rural areas is at its nascent stage. More than one half

of rural households possess a bicycle, only 14% own a two-wheeler and only 1% owns a car. On the other hand, 79% of urban households own a mobile phone, 76% own a television, and 91% own an electric fan. In addition, 33% of urban households now own motorcycles (two-wheelers) and only 6.5% possess a four-wheeled vehicle.

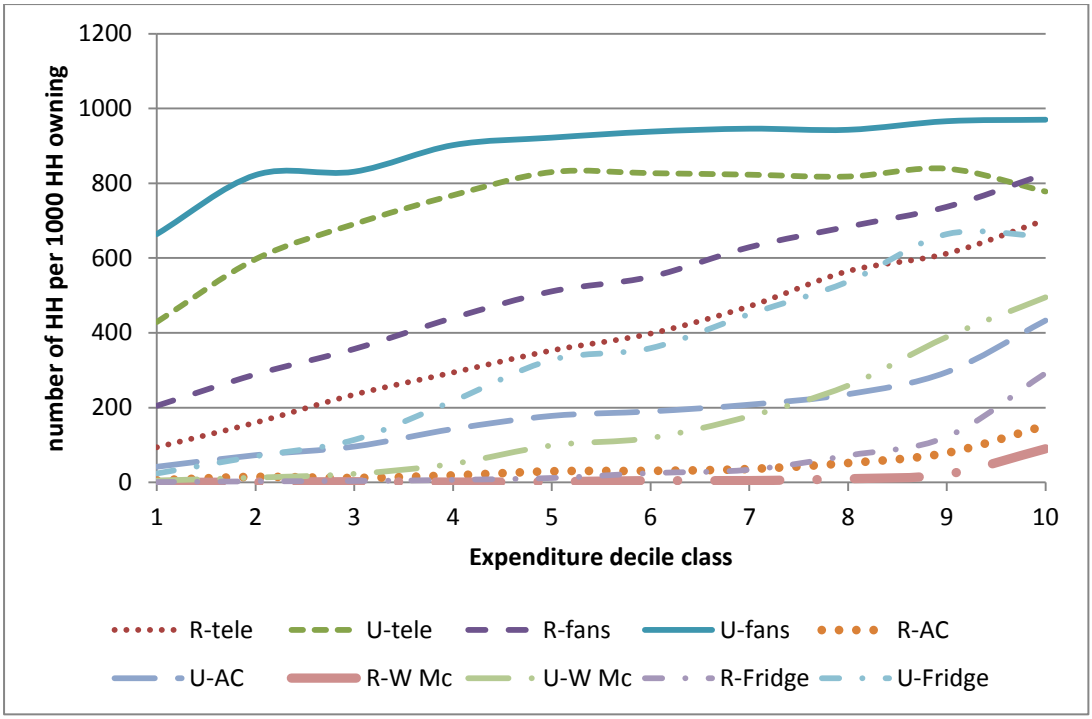
Fig. 11: Ownership pattern of durable goods



Data source: [17]

The difference between the urban and rural living by income class becomes very clear from Fig. 12. For example, whereas 43% and 66% of lower income class households own television sets and electric fans respectively in urban areas, the share falls to 10% and 20% respectively in rural areas. But as income increases, the ownership level increase proportionately in rural areas whereas in urban areas it reaches a saturation level beyond 4th expenditure decile. While durable goods like air-conditioners, washing machines and refrigerators are used only by the richest segment of the rural population, these appliances are becoming more popular with urban consumers and an increasing level of ownership of such appliances is found as income grows. This implies that an urban consumer is likely to lead a more energy-intensive life as income increases.

Fig. 12: Ownership pattern of electric appliances by expenditure decile class



Data source: [17]

4.0 Effects of India's transformation on future residential energy demand

This section presents the approach used in this study (section 4.1) and the main results (section 4.2).

4.1 Approach

The effect of demographic change, economic growth and life-style change on future residential energy demand is analysed below using a disaggregated, end-use modelling approach. The analysis is carried out as follows (see Fig. 13 for a schematic showing the details):

- Energy consumption information for the urban and rural population per income class (in per capita terms in physical units) is taken from Ref. [17] and is aggregated to three categories to reflect the poor, medium income and high income categories. The 10th decile is considered as the high income group for both areas. For rural poor category, an average of first seven decile classes is considered while for urban poor first six decile classes are considered. The remaining classes are considered as middle income groups. Table 1 presents the energy consumption information for 2010.

Table 1: Energy consumption per capita by income class in the reference case for 2010

	Electricity (kWh/person)	LPG (kg/person)	Firewood (kg/person)	Kerosene (l/person)	Coal (kg/person)
Rural-Low	4.65	0.084	23.85	0.08	0.305

income					
Rural – Middle Income	9.88	0.526	29.63	0.897	0.322
Rural – High income	17.92	1.846	27.182	0.834	0.463
Urban – Low income	13.63	1.681	9.123	0.787	0.99
Urban – middle income	31.7	3.63	2.175	0.474	0.256
Urban – high income	65.75	4.45	1.159	0.228	0.064

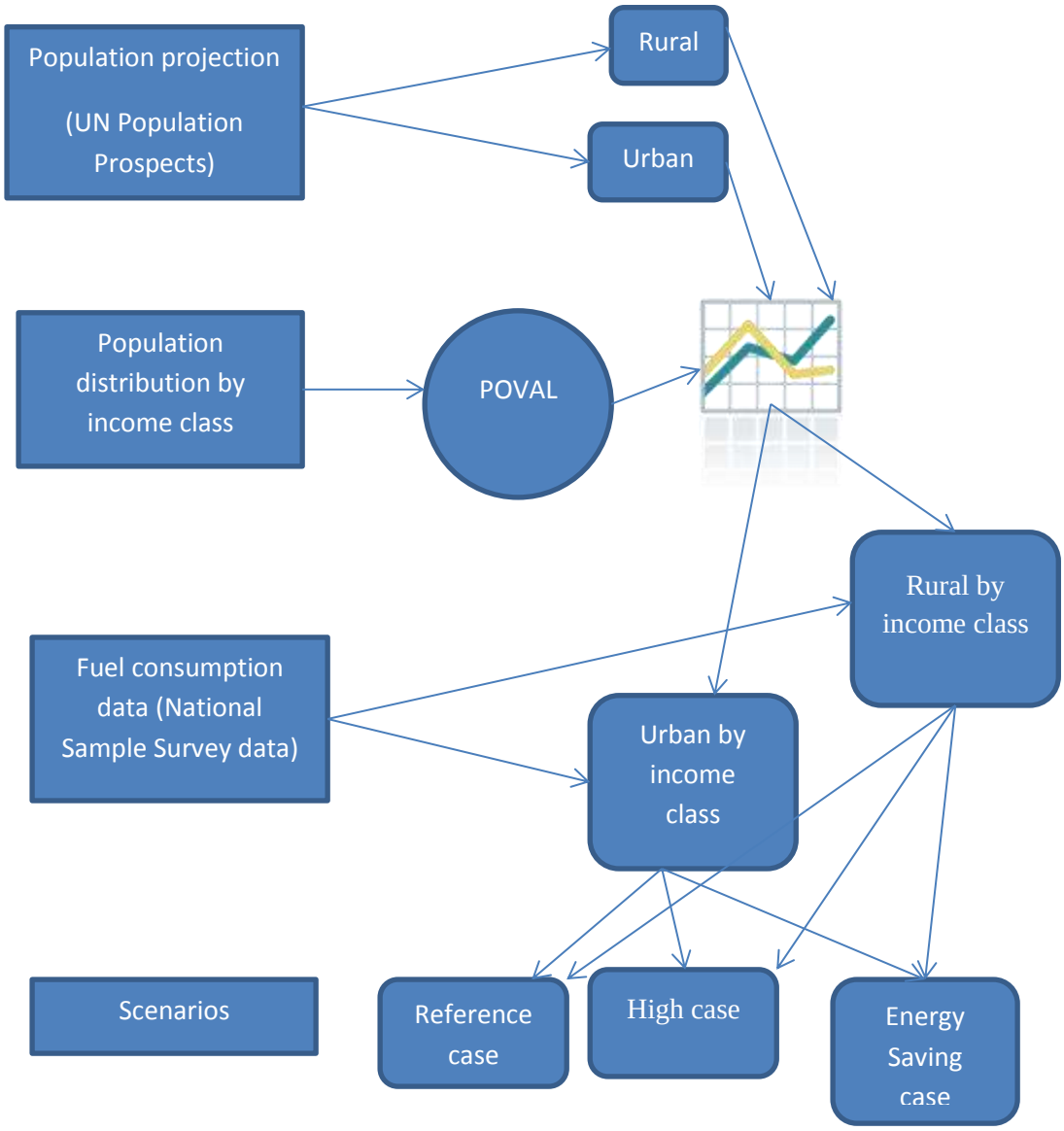
Source: Based on [17]

- Fuel-wise energy consumption is obtained by multiplying consumption per person with the relevant population size. The population size is obtained from the population forecast [1], urban-rural share of the population [1] and distribution of population by income class shown in Fig. 6 and 7.
- The results obtained for the reference case in 2010 are calibrated and reconciled against 2009 energy consumption data.
- The analysis is based on three scenarios:
    - The reference scenario assumes that per person energy consumption in 2010 grows at an annual growth rate of 2% per year for the entire period. The commercial energy demand per person in the residential sector grew at 2.4% per year on average between 1990 and 2010. The growth rate in the reference scenario follows this historical trend.
    - A high demand growth scenario is considered following an assumed growth path as given below:
        - It is assumed that each group will progress trying to emulate the consumption pattern of the high end consumers within the respective groups. It is assumed that low and middle income groups will achieve this consumption pattern by 2020 and then the demand per person grows at 3% per year for electricity and LPG while firewood, kerosene and coal demand declines by 1% per year. This is based on the view that low and medium income groups will progressively turn away from dirty fuels and turn to modern energies as time passes.
        - For the high income category, a growth rate of 3% per year in considered for electricity and LPG consumption compared to that in 2010. This is higher than the average growth rate for commercial fuels and is used to capture a likely faster growth in modern fuel demand by these consumers. For urban consumers, coal and firewood consumption is assumed to decline to zero over the study horizon and minimal kerosene consumption for stand-by use is assumed. For rural consumers, 1% decline rate is used for firewood and coal, while kerosene consumption is assumed to remain unchanged.
    - An efficient energy scenario where energy demand reduces by 1% in every year compared to the high growth scenario. This scenario captures the possibility of energy efficiency improvement over the 20 year study horizon. Ref. [28] indicates

that Autonomous Energy Efficiency Improvement of 1% per year is commonly used in energy forecasting models. Although multiple energy improvement scenarios can be designed, for simplicity only one case is considered but this allows us to explore the energy saving potential in the residential sector.

- The analysis was done for a period of 20 years (until 2030) taking a five-year snap-shot.

Fig. 13: Schematic indicating the methodological framework

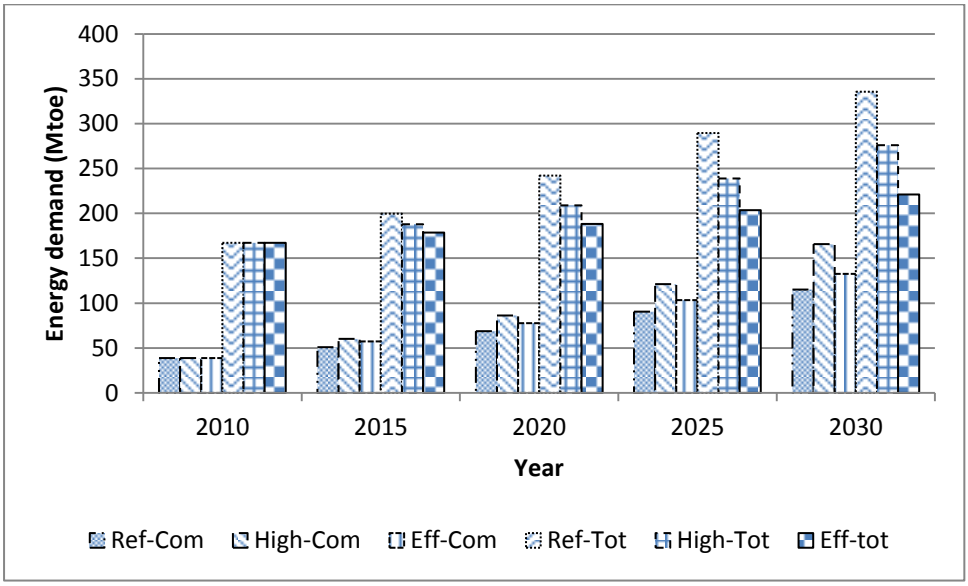


Although the analysis follows a simple framework, it provides useful insights because of the disaggregated level of analysis that captures the urban/ rural differences in energy demand, fuel mix diversity and the shift along the energy ladder of a developing economy.

4.2 Main findings

The total residential energy demand in India under three different scenarios is presented in Fig. 14. It provides the commercial energy demand and the demand including firewood[1]. It can be seen that in the reference scenario the commercial energy demand is likely to increase to 115 Mtoe by 2030 from 39 Mtoe in 2010. Thus the business as usual case would require an additional 76 Mtoe of commercial energy for the residential sector. This represents an annual demand growth rate of 5.6% over the study period. If the demand for firewood is added, the demand growth rate becomes moderate (1.5% per year), as the firewood demand grows at a much slower pace. It needs to be mentioned here that in the reference scenario modern energies play a minority share up to 2025, and only in 2030, the commercial energy displaces firewood as the main source of residential energy.

Fig. 14: Residential energy demand outlook for India



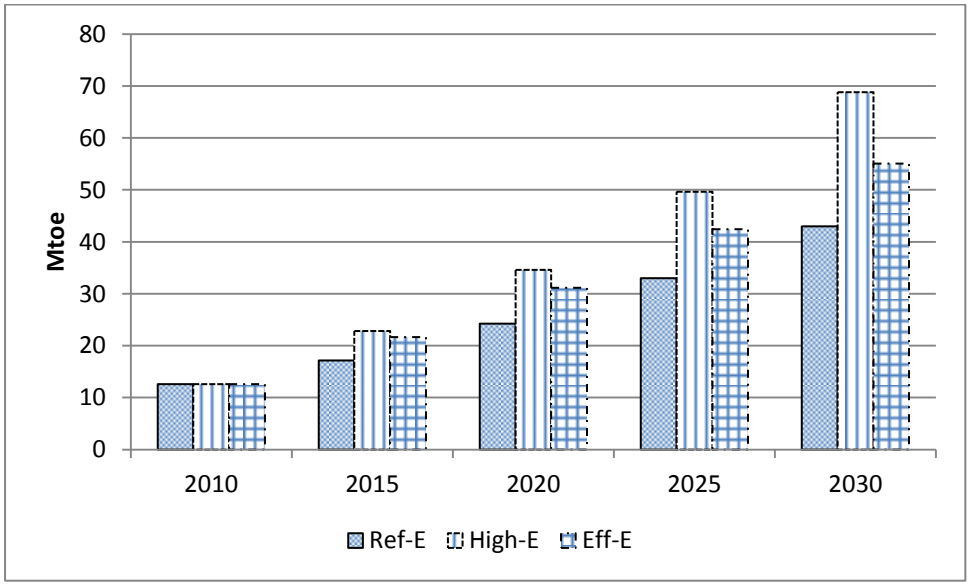
The picture changes substantially in two alternative scenarios. The commercial energy demand increases faster in the high scenario (at 7.5% per year), thereby quadrupling the demand by 2030 compared to 2010. This implies that the country would need an additional 50 Mtoe of energy in 2030 following the high scenario compared to the reference scenario. However, even in this scenario, the firewood demand remains 40% of the total demand in 2030, which can put significant pressure on wood resources in the country. Most of the firewood consumption takes place in rural areas and in poorer households. This clearly highlights the importance of greater support for promoting clean cooking energies in the country. On the other hand, the efficiency improvement scenario results in a slightly higher commercial energy demand compared to the reference case but yields the lowest total demand of three scenarios. Because energy efficiency improvement is applied on the high demand scenario, the outcome related to commercial energy demand is not surprising. The lowest total demand is obtained as firewood saving through efficiency improvement occurs in this case.

[1] By commercial energy we mean energies that are sold in the market and bear a price. These are coal, LPG, electricity and kerosene in our case. Firewood, although enters in the market in many places, is still collected and used.

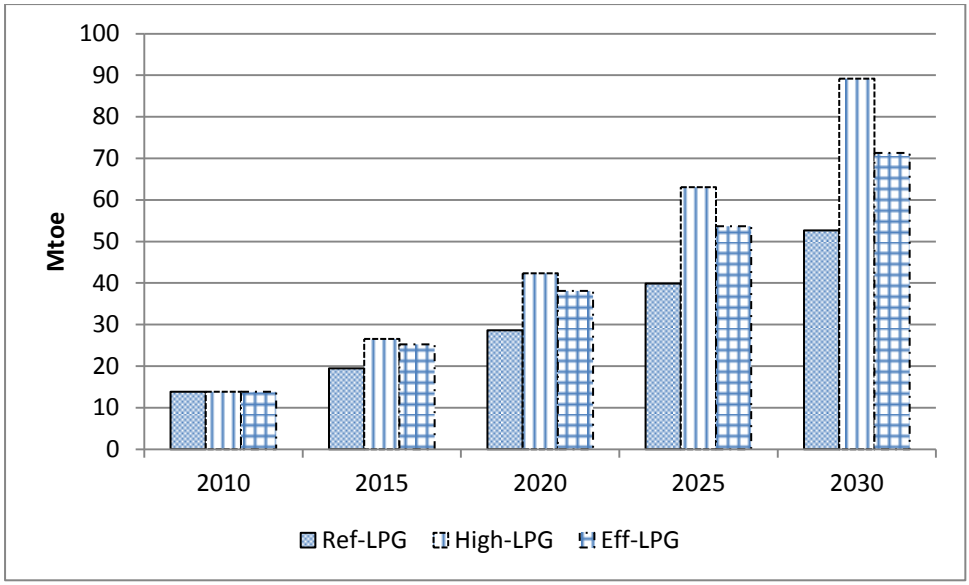
In terms of fuels, similar interesting insights are obtained from Fig. 15. Electricity demand increases more than 3.5 times by 2030 (6.3% demand growth per year on average) in the reference scenario while LPG demand quadruples (6.9% demand growth per year). In fact, these two forms of energy drive the demand the commercial energies in the residential sector. In the high scenario, electricity demand grows almost 9% per year while LPG demand grows at 10% per year. Such explosive demand growths can be somewhat tamed if energy efficiency measures are considered (as shown by the efficiency improvement scenario), which offers a window of opportunity. However, more aggressive efficiency improvements would be required to manage the residential energy demand in the future. The demand growth assumes importance given that India has a relatively high primary energy input requirement for every unit of electricity consumption. Reference [9] reports that due to relatively low conversion efficiency of electricity generation and a high transmission distribution loss, India used 4.2 units of primary inputs for each unit of electricity generated in 2005. This implies that a rapid growth in electricity demand requires a four-fold consequential increase in electricity generation to meet the demand, provision of which can itself be a major problem. If the additional generation comes from coal-based power plants following the current trend, the environmental implications at the local and global levels of demand growth can be significant.

Fig. 15: Indian residential energy demand forecast

15(a): Electricity demand

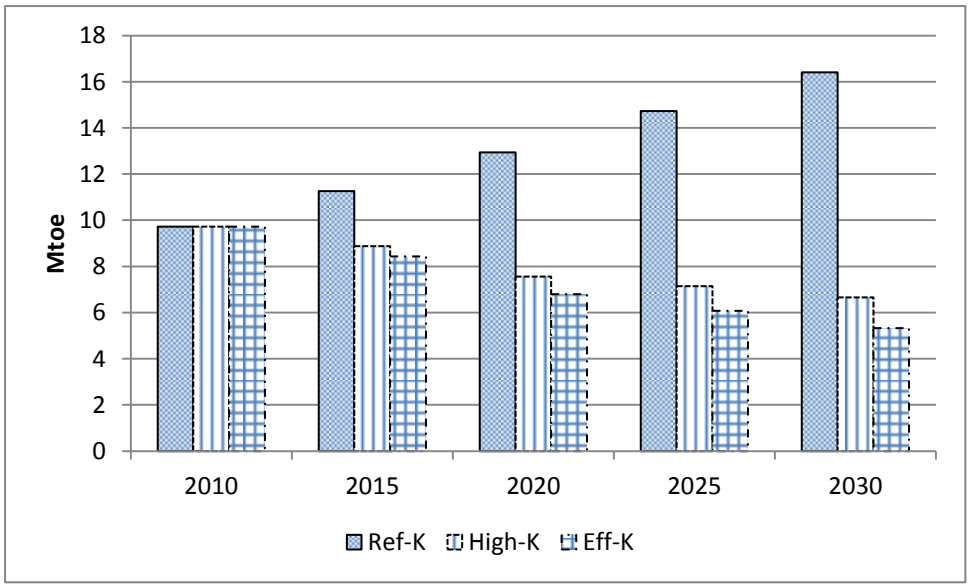


15(b) LPG demand

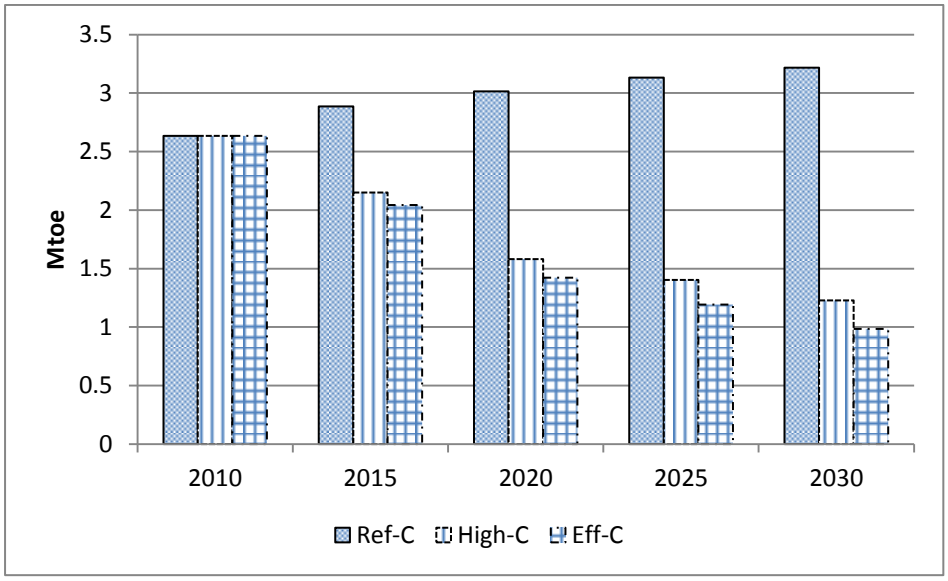


However, a rapid growth in electricity and LPG is likely to reduce the reliance on dirty fuels such as kerosene and coal. In the reference scenario, the demand for kerosene and coal grows relatively slowly. Kerosene demand grows at 2.6% per year on average while coal demand grows at 1% per year. Most of the consumption continues in the rural areas and the poorer households continue to rely on them. Both fuels see a dramatic decline of their demand in the high scenario as electricity and LPG displace them. The demand falls further in the efficiency improvement scenario. Economic and demographic transition in the country has the potential to drive a transition to modern energies in the country.

15(c) Kerosene demand

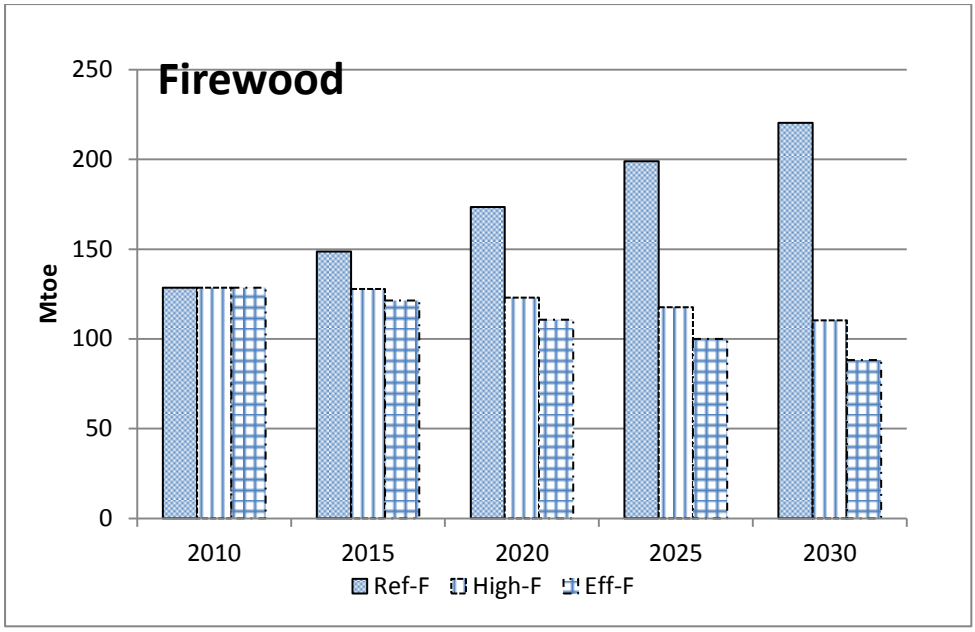


15(d) Coal demand



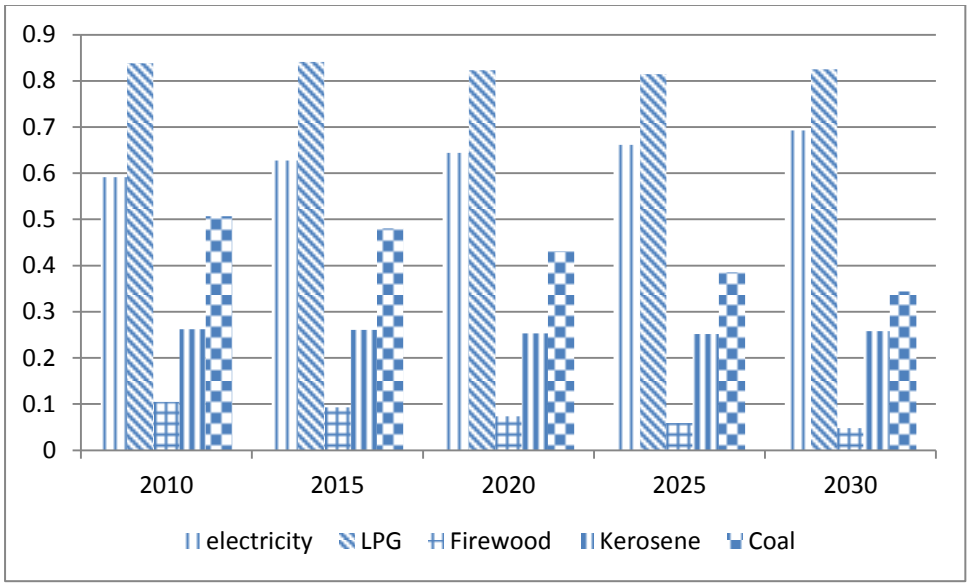
The demand for firewood continues to grow in the reference scenario (see Fig. 16) to reach 220 Mtoe in 2030 from 128 Mtoe in 2010 (an annual growth rate of 2.7%). This substantial demand growth is fuelled by middle income consumers in rural areas supplemented by the low income consumers in rural and urban areas. This happens due to the bigger size of the middle income group over the study period, and the continued reliance on firewood in the reference scenario following the historical demand pattern. However, the firewood demand declines sharply in the high scenario and efficiency improvement scenario. In fact, firewood demand in the high scenario in 2030 will be about 50% of the reference scenario and the demand in 2030 is likely to be lower than the demand in 2010, suggesting the potential for a major residential energy transition in India where biomass does not dominate in the residential energy mix. However, as indicated earlier, even then about 40% of total energy in the sector will be supplied by biomass in 2030, mostly in rural settings and therefore continued emphasis on the promotion of efficient cook-stoves remains a priority to ensure reduced health impacts due to biomass use in the residential sector.

Fig. 16: Firewood demand in India



It is also interesting to note that the modern energy demand in driven by the urban population (see Fig. 17) and this continues until 2030, despite the growing middle class in the rural areas. The urban share of electricity is expected to increase to 70% by 2030 from 60% in 2010 in the reference case. In the high scenario, the urban share of electricity demand increases even further to 80%. The share of LPG remains even higher at above 78%. On the other hand, rural areas dominate in coal, firewood and kerosene.

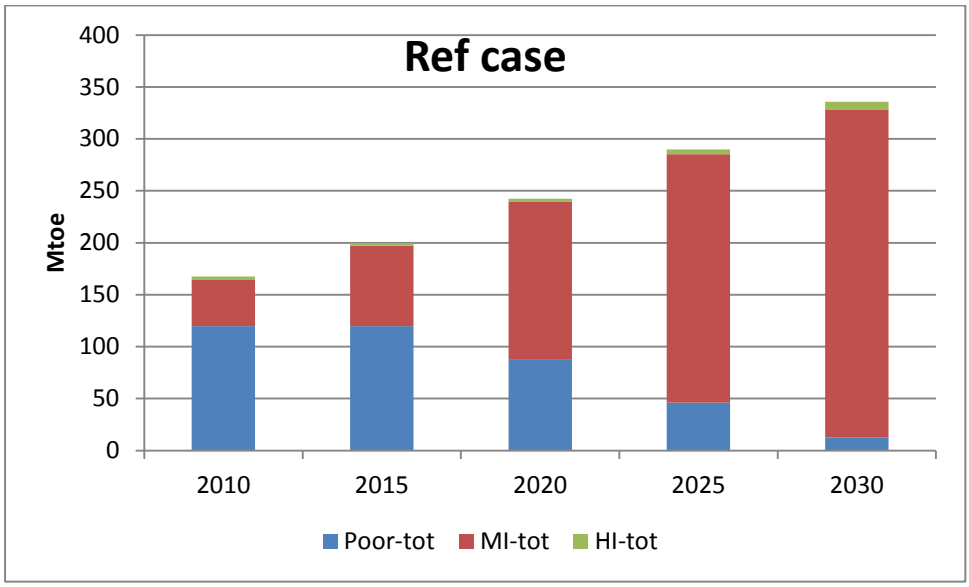
Fig. 17: Urban share in the residential energy demand (reference case)



Finally, the energy demand by income class reveals the growing importance of the middle income class in the economy. High share of energy demand (including firewood) from the poor declines over time and the share of the middle income group increases. By 2030, the middle income group will completely dominate the energy demand (See Fig. 18). The rise in the number of middle income

population is responsible for such a transition and highlights the need to pay greater attention to this section of the population in order to manage the demand in the future. The situation is slightly different for commercial energies where the share of the high income group increases slightly over time as well but the middle income group continues to dominate in all scenarios.

Fig. 18: India's residential energy demand outlook by income class



In summary, the demographic changes, economic growth and consequent life-style changes will bring profound changes in the residential energy consumption in India over the next 20 years. The demand for commercial energies will rise rapidly and the emergence of a large middle income group is likely to drive energy demand. Rapid urbanisation of the country is also likely to increase the commercial energy demand from urban consumers. As electricity and LPG are likely to become the preferred fuels of the urbanised population, India will need a rapid expansion of its supply infrastructure to cope with such a transition.

5.0 Conclusions

India is transforming very rapidly. It is urbanising at an unprecedented rate and under the influence of fast economic growth and demographic transition, the country is fast changing. As a consequence, the incidence of poverty is reducing in the country and the size of the middle income group is growing fast. As the population becomes wealthier and urbanised, their consumption behaviour is changing. The demand for modern energies is growing rapidly due to growing penetration of energy intensive appliances and consumer goods. If these trends continue over the coming decades, the country will see a significant growth in its residential energy demand, resulting in a 3 to 4 fold rise in commercial energy use in the sector by 2030. Electricity and LPG will emerge as the preferred fuels accounting for 83 to 95% of commercial energy demand in different scenarios. However, while the biomass use slows down, it can account for 40% of total energy demand in the sector particularly due to continued reliance of rural poor and middle income classes on this fuel. There lies the

prospect of an energy transition in the residential sector thereby ending the age-old domination of biomass by modern commercial energies. The middle income group will emerge as the dominant source of fuel demand in the residential sector which is in line with the emergence of a dominant middle class in the country.

Clearly, the burgeoning energy demand from the residential sector has significant implications.

a) First, ensuring adequate supply to match 3 to 4 fold rise in commercial energy demand remains a challenge. Electricity supply in particular requires a special mention. Already electricity supply is unreliable in India and there is a chronic supply-demand mismatch problem in the country, with peak demand exceeding supply on a regular basis. In addition, the inefficient system imposes a very high primary energy input demand for every unit of electricity consumed (a factor of 4.2 indicated in [9]). Meeting the growing electricity demand therefore requires expanding the primary fuel supply system at a much faster rate and well in advance to ensure adequate fuel supply. But given India's high reliance on coal for its electricity supply, this is likely to mean developing more coal supply infrastructure (e.g. coal mines and coal transportation and handling) and coal-based thermal power plants with consequential local and global environmental impacts.
b) Second, despite growing importance of commercial energies in the residential sector fuel mix, solid biomass use continues in the country. 40% of the total sectoral energy demand in the business-as-usual case comes from this resource and the quantity can grow almost 70% compared to 2010 level by 2030. This also adds to the environmental damage arising from the increased likelihood of deforestation consequent to the additional pressure on forests for the biomass supply. In addition, the poor and middle income rural households as most likely to users of this resource will encounter significant health and occupational hazards and the society will bear the burden of external costs.
c) Third, rapid demand growth and a transition to modern energies is likely to accelerate India's fuel imports due to India's limited endowments of petroleum resources and poor quality of its coal reserves. This exposes the country to a higher risk of fuel price fluctuations, higher fuel import bills, and to higher fuel prices in the future. Being the dominant player in sector, the middle income group will bear most of the effects. The security of supply concern can become important as a result, which requires further investigation.
d) Fourth, the environmental consequence of growing residential energy demand cannot be underestimated either.

However, there is a window of opportunity to manage the residential energy demand taking advantage of efficiency improvements. Using an Automatic Energy efficiency Improvement of 1% per year, this study shows that about 20% of demand in high scenario can be reduced by 2030. At the time when the middle income group is growing and the appliance stock is starting to build up, it is important to ensure that the most efficient appliance stock is build. While the Indian government has introduced the Energy Conservation Law in 2001 and created the Bureau of Energy Efficiency in 2002, and is actively promoting energy demand management, greater emphasis on the residential sector and better policy co-ordination at different levels of the government is essential for greater impact-generating outcomes. Missing this opportunity can prove to be costly in the long-run.

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